MP MASTER
MA24490

WAVEFORM ANALYSER A321

INSTRUCTION MANUAL

WAYNE KERR

WAVEFORM ANALYSER A321

THE WAYNE KERR LABORATORIES LIMITED

ROEBUCK ROAD · CHESSINGTON · SURREY · ENGLAND

Telephone: LOWER HOOK 1131

CONTENTS

	PAGE
INTRODUCTION	**5**
SPECIFICATION	**6**
OPERATING PRINCIPLES	**7**
OPERATING INSTRUCTIONS	**8**
Power supply	**8**
Controls	**8**
Setting-up the analyser	**8**
Signal analysis	**9**
Selective voltmeter	**10**
Hum level	**10**
TECHNICAL DESCRIPTION	**12**
General	**12**
Power supplies	**12**
Local oscillator	**13**
Input amplifier	**13**
Balanced modulator	**15**
100kc/s crystal filter	**15**
100kc/s tuned amplifier	**16**
MAINTENANCE	**17**
Performance test	**17**
Voltages	**17**
Re-adjustment and re-alignment	**19**
Components list	**21**

TABLES

Table 1	Decibels and equivalent voltages	**11**
Table 2	Typical performance figures (sawtooth waveform)	**12**
Table 3	Typical voltages	**18**

ILLUSTRATIONS

Fig. 1	Block diagram	**7**
Fig. 2	Power supply	**12**
Fig. 3	Local oscillator	**13**
Fig. 4	Balanced input	**14**
Fig. 5	Input amplifier	**14**
Fig. 6	Balanced modulator	**15**
Fig. 7	100kc/s crystal filter	**16**
Fig. 8	100kc/s tuned amplifier	**16**
Fig. 9	Biased diode circuit	**17**
Fig. 10	Location of major components	**20**
Fig. 11	Circuit diagram	**23**

METER TIME CONSTANT
LONG
SHORT
FINE FREQUENCY
FREQUENCY RANGE

INTRODUCTION

The audio frequency Waveform Analyser A321 meets the need for a portable instrument which is simple to operate and yet possesses the high degree of selectivity required for modern low-frequency design work.

Using the instrument, direct measurements can be made of the relative levels of the components of a complex waveform, to a value −55dB below the fundamental for frequencies less than 100c/s, and to −75dB below the fundamental for frequencies between 100c/s and 20kc/s. The input level of the fundamental can be any value between −20dB and +30dB, relative to 1mW into 600Ω. Since the instrument is effectively a selective high gain amplifier, and is stable to within 1dB over a period of an hour for any setting, it can also be employed as a selective voltmeter (e.g. for use as a detector for the Wayne Kerr Universal Bridge B221). The lowest calibrated level of the instrument corresponds to an input of 14 μV; an input of 1 to 3 μV will produce a readable deflection.

The analyser employs superheterodyne principles and utilizes sharply tuned crystal filter circuits to obtain the high degree of selectivity. The meter is protected against overloading caused by excessive input signals. For simplicity of operation, the number of controls fitted has been kept to a minimum.

SPECIFICATION

FREQUENCY COVERAGE

20c/s to 20kc/s in two overlapping ranges: 20c/s to 1200c/s and 1kc/s to 20kc/s.

FREQUENCY STABILITY

Better than 1%.

FREQUENCY RESPONSE

Within ±1dB over the working range.

ACCURACY

Frequency calibration ±2% over major part of scale.

Harmonic measurement Above 100c/s, to −75dB with an accuracy of ±5% or ±1dB, whichever is greater.

Below 100c/s, to −55dB with an accuracy of ±5% or ±1dB, whichever is greater. (Distortion measurements below 100c/s are limited by the hum level; this level varies, but never exceeds −55dB).

INPUT

Level Between −20dB and +30dB (relative to 1mW into 600Ω, i.e. 0·775V) by a 10dB per step switch and a fine adjustment control. Equivalent voltage range is 77·5mV to 24·5V.

Impedance 600Ω and 100 000Ω unbalanced.
600Ω and 25 000Ω balanced to special order.

LEVEL STABILITY

±1dB provided that the mains voltage is constant to within ±5%.

SELECTIVITY

Constant over the frequency range. Flat-top pass band of 10c/s ±1c/s. Response with respect to mid-band (approximate figures):
10c/s: −25dB **20c/s:** −38dB **45c/s:** −55dB

LOCAL OSCILLATOR

Frequency Adjusted during measurement to be 100kc/s minus input signal frequency.

Carrier Suppression 40dB for average time of measurement. Long term suppression 20dB to 25dB.

HUM LEVEL

−55dB.

POWER SUPPLY

110V to 120V in 5V steps, 200V to 250V in 10V steps, 40c/s to 60c/s single phase. Power consumption approximately 60 watts.

DIMENSIONS

20 in. × 9 in. × 9 in. (50·8 cm × 22·9 cm × 22·9 cm) in transportable case. Suitable for rack-mounting when removed from case.

WEIGHT

31 lb. (14 kg).

OPERATING PRINCIPLES

The analyser employs a variable-frequency local oscillator (fig. 1) which is adjusted, during measurement, to provide an upper side-frequency of 100kc/s with the fundamental or selected harmonic of the input signal. Adjustment of the oscillator frequency between 80kc/s and 100kc/s is facilitated by a main tuning control and a FINE FREQUENCY control, the frequency coverage being made in two overlapping ranges, selected by a FREQUENCY RANGE switch. The two scales of the main tuning control are calibrated in terms of the input signal frequency required to produce the 100kc/s side frequency; lamps are fitted to indicate which of the two scales, ZERO to 1200c/s or 1kc/s to 20kc/s, is in use.

The input signal is applied via a switched attenuator (INPUT LEVEL—COARSE) to an amplifier, which contains a FINE control for attenuating the input to any level over the 10dB steps of the COARSE control. The range of inputs accommodated by the combined use of the COARSE and FINE controls is from −20dB to +30dB, relative to 1mW into 600Ω. A 600Ω resistor can be connected across the input terminals by a 600 OHM LOAD switch, for setting-up and test purposes.

The local oscillator output is modulated by the amplifier output (input signal) in a bridge modulator circuit. The bridge is balanced to suppress the carrier frequency by a BALANCE R control and a BALANCE C control, so that the bridge output consists of the two side-frequencies only. The upper side-frequency is selected in a two stage crystal filter circuit, which has a flat-top characteristic extending to ±5c/s of the mid-band frequency, 100kc/s. The selectivity curve falls rapidly beyond this range, the approximate figures from mid-band being −25dB at ±10c/s, −38dB at ±20c/s and −55dB at ±45c/s.

The crystal filter output is fed via a HARMONIC LEVEL attenuator control, which is calibrated from 0 to −55dB in 5dB steps, to a four-stage selective amplifier. The meter bridge circuit, arranged to limit the meter current for protection against damage by overload, is connected to the output of the tuned amplifier. The meter is calibrated from +2dB to −20dB which, in conjunction with the HARMONIC LEVEL control, gives a measuring range of +2dB to −75dB. A long time constant network can be connected across the meter by the METER TIME CONSTANT switch, to reduce the effects of any jitter which may be present.

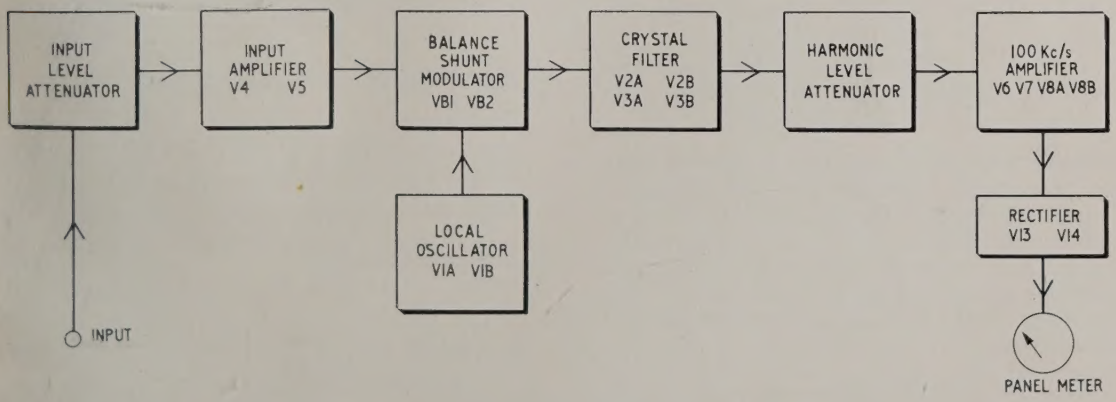

Fig. 1 Block Diagram

OPERATING INSTRUCTIONS

POWER SUPPLY

The Analyser is set to operate from 230V a.c., 40c/s to 60c/s supplies. If any other power supply is to be used, the tappings on the primary of the power transformer must be appropriately adjusted. When the instrument is supplied for 110 to 120V operation fuses FZ1 and FZ2 are of 4A rating. The transformer tapping panel and fuses are located on the underside of the chassis, accessible when the instrument has been withdrawn from the case.

The instrument is supplied with a wired-in power supply cable, connected to the input switch via a grommet hole in the front panel. A suitable 3-pin plug must be connected to the cable, the wires being identified as follows:

Red — Live Black — Neutral Green — Earth

A good earth connexion is essential to avoid unnecessary hum pick-up.

CONTROLS

The controls used for making measurements are located on the front panel and, briefly, they function as follows:

Main tuning control: This has two scales (ZERO to 1200c/s and 1kc/s to 20kc/s) and is adjusted to the fundamental or required harmonic of the input frequency. A red pilot lamp lights adjacent to the scale in use.

FREQUENCY RANGE ***switch:*** This enables the required frequency range to be selected. It has two positions; LOW (zero to 1200c/s range) and HIGH (1kc/s to 20kc/s range). The switch also completes a circuit to light the appropriate scale indicator lamp on the main tuning dial.

FINE FREQUENCY ***control:*** This is used in conjunction with the main tuning control, to provide a fine adjustment of frequency. The control is normally set with its pointer opposite the centre dot whilst the main tuning control is being set as closely as possible to the required frequency. The FINE FREQUENCY control is then used for the final adjustment.

INPUT LEVEL ***controls:*** These comprise a COARSE control, calibrated from −20dB to +20dB in 10dB steps, and a FINE control which provides attenuation to any level up to 10dB on each 10dB step. The total coverage is from −20dB to +30dB, equivalent to voltage inputs of 77·5mV to 24·5V.

Note: The FINE control is calibrated from 0 to 10dB. To check this calibration to within ±0·2dB, tune to the fundamental of a given input frequency and, with the FINE control set to zero, adjust the input signal level until the panel meter reads zero. Setting the FINE control to any given position will then produce a reading on the meter, indicating the attenuation and enabling the accuracy of the control calibration to be ascertained.

Balance controls: These comprise a BALANCE R and a BALANCE C control, which are adjusted in turn to suppress the carrier frequency from the modulator output.

HARMONIC LEVEL ***switch:*** An attenuator control extending the range of the panel meter from +2dB/−20dB to −53dB/−75dB in 5dB steps, enabling the level of a harmonic to be measured with respect to the fundamental. This control should not be used to provide 'attenuation' of the input signal.

METER TIME CONSTANT ***switch:*** This has two positions, LONG and SHORT, and enables the effects of jitter on the meter needle to be reduced. When searching for harmonics (using the main tuning control), it is advisable to set the switch to the SHORT position.

600 OHMS LOAD ***switch:*** This switch connects a 600Ω resistor across the input terminals, for setting-up and test purposes, and for measurements made at the end of unterminated 600Ω lines.

SETTING-UP THE ANALYSER

Switching on

For accurate readings, the instrument should be switched on at least half-an-hour before use, in order that it may reach thermal equilibrium.

Carrier Suppression

The carrier should be suppressed as follows:

a Set the FREQUENCY RANGE switch to the LOW position and the main tuning control to ZERO. Set all other controls to zero.

b Switch in the 600Ω load across the input, and adjust the FINE FREQUENCY control for a maximum reading on the panel meter.

c Adjust the BALANCE R and BALANCE C controls in turn, commencing with the BALANCE R control, until a *minimum* deflection is obtained on the panel meter. Set the HARMONIC LEVEL control during the adjustments to provide a suitable deflection.

Carrier suppression of approximately —40dB can be obtained for the period of average measurement, suppression to greater than —40dB being possible by very precise adjustment of the BALANCE controls. In general it is not necessary to get such a high degree of suppression except for marginal measurements on input frequencies below 100c/s; a nominal suppression of —20dB to —30dB is adequate. Interaction between the INPUT LEVEL—FINE control and the BALANCE controls has been kept to a minimum by adjustment to the instrument at the factory. When performing measurements below 100c/s where carrier suppression below —40dB is essential, it may be necessary to first set the INPUT LEVEL—FINE control to the required point and then to balance out the carrier.

Jitter

When the carrier is being suppressed to a level of —40dB, a certain amount of jitter will be noticed in the meter reading. The jitter can be reduced by setting the METER TIME CONSTANT switch to the LONG position. Jitter is caused by the extreme sensitivity of the instrument to low frequency surges at the ZERO setting of the main tuning control. The effect is seldom present when an input signal is applied to the instrument.

Excessive jitter when balancing the carrier may be due to the contacts of the BALANCE R and BALANCE C controls; these may be improved by rotating the knobs a few times. Further information regarding jitter is given in the maintenance section of this handbook.

SIGNAL ANALYSIS

Known fundamental frequency

For signals below 100c/s (fundamental), suppress the carrier to —40dB; for signals above 100c/s, a carrier suppression of —20dB to —25dB is adequate. Then:

a Connect the signal to the input terminals by means of a screened cable. (Note that the d.c. level of an unbalanced input must not exceed 500V; when the balanced input circuit is fitted, d.c. must not be connected across the input terminals).

b Set the INPUT LEVEL—FINE control and the HARMONIC LEVEL control to zero. Select the required frequency range and set the cursor of the main tuning control to the fundamental frequency, indicated by a maximum reading on the panel meter.

c Adjust the INPUT LEVEL controls to give a 0dB reading on the meter, checking that this is the maximum reading by tuning the FINE FREQUENCY control, if necessary.

d Set the cursor of the main tuning control to the lowest harmonic (twice the fundamental), and advance the HARMONIC LEVEL control until a readable deflection is obtained on the meter, re-tuning the FINE FREQUENCY control for maximum deflection, if necessary. The level of the harmonic can now be read by taking the algebraic sum of the HARMONIC LEVEL control setting and the meter reading.

e Repeat the procedure detailed in d for each harmonic frequency.

Note: To obtain the zero meter reading on the fundamental of low level input signals, it may be necessary to re-set the HARMONIC LEVEL control. The value of this setting must then be subtracted from each harmonic reading to give the true harmonic level. Thus, if the HARMONIC LEVEL control is re-set to —30dB, and a harmonic reading of —55dB is obtained, the true harmonic level relative to the fundamental is —25dB (—55dB minus —30dB).

Unknown complex waveform

Suppress the carrier, and

a Set the INPUT LEVEL controls:
COARSE to —20dB FINE to 0dB
and set the HARMONIC LEVEL control to zero.

b Turn the main tuning control *slowly*, exploring the low frequency range and, if necessary the high frequency range.

c As soon as a small meter deflection is observed advance the INPUT LEVEL—COARSE control to —10dB and proceed with the search. Continue until the lowest frequency component of the signal is obtained, and adjust the INPUT LEVEL controls for a 0dB reading on the meter.

d The measurements can then be made as detailed for the 'known fundamental frequency'.

Note: If the unknown waveform contains an appreciable amount of even harmonics, the meter reading will be slightly affected by the polarity of the input, owing to the asymmetry of the waveform. In such instances, provided that the signal source is balanced (i.e. neither side earthed), the input leads should be reversed, and if the harmonic reading differs by more than 1dB to 2dB, the mean of the two readings taken.

SELECTIVE VOLTMETER

Because the analyser is effectively a high gain selective amplifier with a 'level' indicating output, it is eminently suitable for use as a bridge detector (e.g. as a detector for the Wayne Kerr Universal Bridge B221), and as a selective voltmeter. The lowest calibrated level corresponds to approximately 14μV r.m.s. at the input terminals (−95dB on 1mW into 600Ω), this being obtained with the INPUT LEVEL set to −20dB, the HARMONIC LEVEL set to −55dB, and the meter indicating −20dB.

When the analyser is to be used as a bridge detector, suppress the carrier and adjust the main tuning control to the source frequency, using the FINE FREQUENCY control to obtain a maximum reading on the panel meter. The attenuator controls should be set to give a suitable reading. The minimum readable deflection corresponds to a level of 1 to 3μV at the input terminals.

To use the instrument as a selective voltmeter:

a Suppress the carrier as previously detailed.

b Connect the signal input to the analyser and set the main tuning control to the input frequency, adjusting the FINE FREQUENCY control for a maximum reading on the panel meter.

c With the HARMONIC LEVEL control initially set to 0dB, adjust the INPUT LEVEL controls to give a zero reading on the panel meter, re-setting the HARMONIC LEVEL control if necessary.

The input level relative to 0dB (0dB settings of the INPUT LEVEL and HARMONIC LEVEL controls) can be ascertained by taking the algebraic sum of the control settings (and, for very low inputs, the meter reading). For example, with the meter indicating 0dB, the INPUT LEVEL—COARSE control set to −20dB, the INPUT LEVEL—FINE control set to +2dB and the HARMONIC LEVEL control set to −35dB, the relative input level is −53dB (i.e. −20dB −35dB +2dB).

Note: The accuracy of the INPUT LEVEL—FINE control can be checked as detailed in the note given under the heading 'Controls, INPUT LEVEL' (page 8).

The input level relative to any other given level in dB can be obtained by algebraically subtracting the chosen *reference level* from the *indicated level.* For example, with the controls set as previously detailed to give an indicated level of −53dB, and with the reference level taken as −15dB (i.e. an input reference voltage required a setting of −15dB on the INPUT LEVEL controls to produce a 0dB reading on the meter), the relative level would be −38dB (−53dB minus −15dB).

The equivalent voltage for a given relative level in dB can be evaluated from the formula

$$V = \text{antilog.} \left[\frac{XdB}{20} + \log. V_{ref} \right]$$

where V_{ref} = the voltage input required to produce the dB reference level

and XdB = the relative level in dB (sign important)

assuming the source impedance to be constant. Any terminal impedance below 100kΩ (or 25kΩ where the balanced input circuit is fitted) can be used, by suitably shunting the analyser input.

When measuring a source from which it is difficult to obtain a reference voltage, this voltage can be derived from a separate source having the same terminal impedance.

The equivalent voltages for dB relative to 0dB = 0·775V (i.e. 1mW into 600Ω) is given in table 1, based on:

$$V = \text{antilog.} \left[\frac{XdB}{20} - 0{\cdot}111 \right]$$

HUM LEVEL

The normal internal hum level of the instrument can be found by suppressing the carrier, short-circuiting the input terminals, and setting the main tuning control to the frequency of the mains. The hum level is then read as though it were an input signal, and should be at least −55dB. The figure obtained for hum level by this measurement should be subtracted from the reading obtained when measuring input signals with the fundamental at the power supply frequency. The phase relationship between the two signals can be ignored.

TABLE 1

Decibels and equivalent voltages [0dB = 0·775V]

dB	Voltage
+1	0·869V
+2	0·975V
+3	1·09V
+4	1·23V
+5	1·38V
+6	1·55V
+7	1·73V
+8	1·95V
+9	2·18V
+10	2·45V

dB	Voltage
+11	2·75V
+12	3·08V
+13	3·46V
+14	3·88V
+15	4·36V
+16	4·89V
+17	5·48V
+18	6·15V
+19	6·91V
+20	7·75V

dB	Voltage
+21	8·69V
+22	9·75V
+23	10·9V
+24	12·3V
+25	13·8V
+26	15·5V
+27	17·3V
+28	19·5V
+29	21·8V
+30	24·5V

dB	Voltage
−1	691mV
−2	615mV
−3	548mV
−4	489mV
−5	436mV
−6	388mV
−7	346mV
−8	308mV
−9	275mV
−10	245mV
−11	218mV
−12	195mV
−13	173mV
−14	155mV
−15	138mV
−16	123mV
−17	109mV
−18	97·5mV
−19	87mV
−20	77·5mV

dB	Voltage
−21	69mV
−22	61·5mV
−23	55mV
−24	49mV
−25	44mV
−26	39mV
−27	35mV
−28	31mV
−29	27·5mV
−30	24·5mV
−31	22mV
−32	19·5mV
−33	17mV
−34	15·5mV
−35	14mV
−36	12mV
−37	11mV
−38	9·8mV
−39	8·7mV
−40	7·8mV

dB	Voltage
−41	6·9mV
−42	6·2mV
−43	5·5mV
−44	4·9mV
−45	4·4mV
−46	3·9mV
−47	3·5mV
−48	3·1mV
−49	2·8mV
−50	2·5mV
−51	2·2mV
−52	2·0mV
−53	1·7mV
−54	1·6mV
−55	1·4mV
−56	1·2mV
−57	1·1mV
−58	0·98mV
−59	0·87mV
−60	0·78mV

dB	Voltage
−61	691μV
−62	615μV
−63	548μV
−64	489μV
−65	436μV
−66	388μV
−67	346μV
−68	308μV
−69	275μV
−70	245μV
−71	218μV
−72	195μV
−73	173μV
−74	155μV
−75	138μV
−76	123μV
−77	109μV
−78	98μV
−79	87μV
−80	78μV

TECHNICAL DESCRIPTION

GENERAL

The analyser circuits are constructed on a strongly made chassis and front panel, which fit into a light aluminium-alloy case. The chassis is secured in the case by six screws, four at the front panel and two at the rear, and is suitable for rack mounting if desired.

A removable lid is fitted to the case, the lid being held in the closed position by two push-button catches on the case. Carrying handles are provided on the case, and louvres permit the free circulation of air for heat dissipation during operation.

All the controls necessary for the operation of the analyser are mounted on the front panel, the pre-set controls and fuses, etc., being mounted on the chassis (fig. 10). Handles are fitted to the front panel to facilitate its removal from the case, and to protect the panel-mounted components when the chassis is inverted on the bench.

The circuit diagram for the analyser (fig. 11) is located at the end of this handbook, diagrams of the individual circuits being given with their associated text.

POWER SUPPLIES

The power input is connected via on/off switch SW1 and fuses FZ1 and FZ2 to the primary of T1 (fig. 2), which is tapped in steps of 10V to suit supplies within the specified ranges. The value of the fuses depends upon the range of the input supply; for 110V to 120V inputs the fuses are 4A rating, for 200V to 250V inputs the fuses are 2A rating.

Transformer T1 has four secondary windings, one (250V—0—250V at 80mA) providing the h.t. supplies, and the other three (6·3V at 2·5A, 1·0A and 0·6A) the heater supplies. RV8, connected across the input amplifier heater chain (6·3V at 1·0A), enables the hum level to be minimized.

Conventional full-wave rectification (V9) is used for the h.t. supplies, smoothing being provided by capacitive input filter C39a, L6 and C39b. V10 is connected in a bridge shunt stabilizer circuit, to provide a stable h.t. supply which is practically unaffected by supply fluctuations. The hum level of the stabilized line can be minimized by RV7, which controls the standing bias to V10.

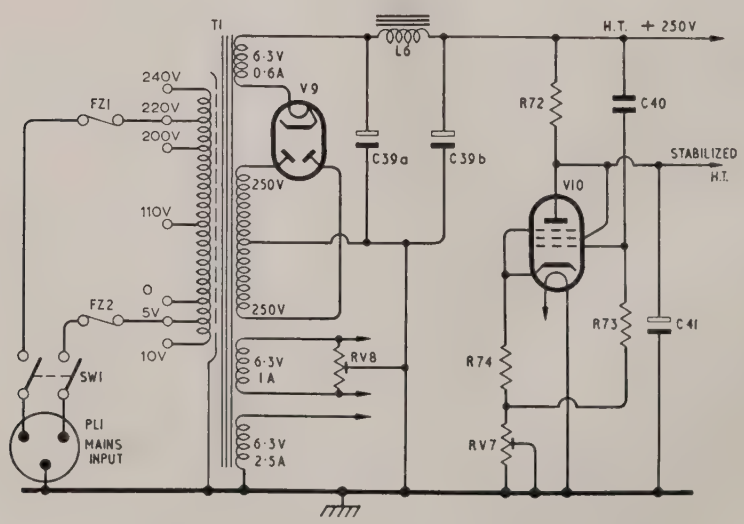

Fig. 2 Power Supply

LOCAL OSCILLATOR

The local oscillator (fig. 3) is based on a circuit described by J. K. Clapp*, in which the tank circuit is a series combination of inductance and capacitance. The frequency stability of this type of oscillator is high—the circuit used in the analyser has a long term stability better than 1% and a short term stability better than 0·01%.

The oscillator has two overlapping frequency ranges (100kc/s to 98·8kc/s and 99kc/s to 80kc/s), the major frequency-determining components for each range being inductor L2 and either section A or sections B and C of the 3-gang variable capacitor VC1. This capacitor forms the main tuning control, and is associated with a dial which has an engraved scale for each of the two ranges. The scales are calibrated ZERO to 1200 (oscillator frequencies 100kc/s to 98·8kc/s) and 1 to 20 (oscillator frequencies 99kc/s to 80kc/s), indicating the input frequency required to produce an upper side-frequency of 100kc/s. Selection of the required range (i.e. variable capacitor circuit) is made by means of the FREQUENCY RANGE switch SW4, which also completes a circuit for the appropriate lamp LP1 (low frequency range) or LP2 (high frequency range), to indicate which of the two frequency scales is in use.

When SW4 is set to the LOW position, the VC1A (12pF to 117pF) circuit is selected, VC2 and VC3 being trimmers for this range. In the HIGH position of SW4, the parallel combination VC1B and VC1C (14pF to 532pF) is selected. A fine adjustment of frequency is provided by parallel-connected variable capacitor VC5 (3pF to 10pF), while VC4 is a trimmer for both frequency ranges.

To maintain oscillations, the oscillator valve V1a employs cathode-grid feedback, applied via the divider network C5 and C6. The cathode output of V1a is fed, via C7 and R5, to the grid of V1b, which is connected in an amplifier circuit. The anode load for V1b is formed by transformer TA, the secondary output of which is applied to the balanced modulator circuit.

The stabilized 200V supply is used to provide the h.t. for the oscillator circuit, which is enclosed in a screening can to avoid break-through of the carrier.

INPUT AMPLIFIER

The amplifier can be fitted with one of two types of input circuit; one (normally fitted) providing an unbalanced input impedance of 100kΩ, and the other a balanced input impedance of 25kΩ.

The balanced input circuit (fig. 4) consists of a 25kΩ : 100kΩ matching transformer, with a capacitor connected across the secondary winding to compensate for transmission loss at high audio frequencies. The capacitor, which has a value in the range 0·0005μF to 0·001μF, is selected to give a level response over the working frequency range.

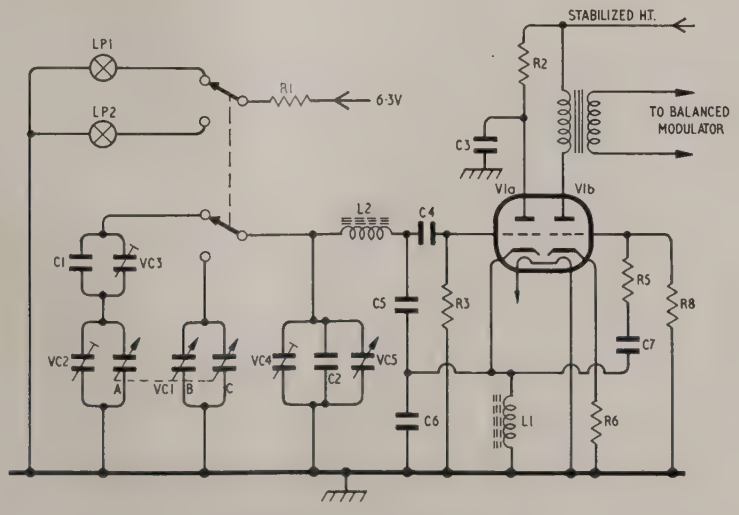

Fig. 3 Local Oscillator

* *J. K. CLAPP: An Inductance-Capacitance Oscillator of unusual Frequency Stability. Proc. I.R.E.* 36, 356 (1948).

The transformer has a mu-metal core and is mu-metal shielded. In spite of the care taken in design, a small amount of harmonic distortion is introduced by the transformer; this can normally be ignored, however, for distortion measurements above 0·5%. The balanced input circuit produces a gain of approximately 1 : 1·72 (5dB) compared with the unbalanced input circuit, due to the use of the transformer: a pre-set potentiometer in the amplifier output circuit enables the overall gain of the amplifier to be adjusted to the correct level.

An earth terminal (TP3) is included on the balanced input panel to facilitate the connexion of unbalanced inputs, one of the balanced input terminals (TP1 or TP2) being strapped to TP3 for this purpose. Two jacks, J1 and J2, are parallel connected across the input terminals TP1 and TP2, for use with plug-fitted input leads.

An 'unbalanced input' instrument should be returned to Wayne Kerr if it is desired to have a 'balanced input' circuit fitted.

The unbalanced input circuit arrangement is shown in fig. 5. C24 (0·5μF, 500V d.c. wkg), in series with this input, forms a blocking capacitor: the input must not be connected to circuits at a higher potential than 500V d.c.

To facilitate setting-up and for measurements on unterminated 600Ω lines, a 600Ω resistor (R75) is

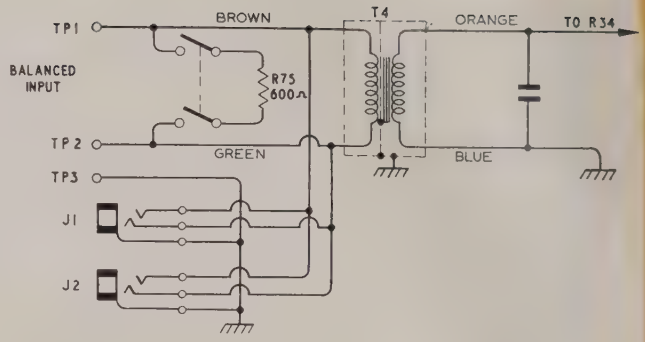

Fig. 4 Balanced Input

connected across the input terminals (balanced or unbalanced circuit) via the 600 OHMS LOAD switch SW6.

The signal to be analysed is applied, via the input circuit, across the potentiometer network formed by R34 to R38 (fig. 5). This network, in conjunction with SW2 (INPUT LEVEL—COARSE), provides a coarse attenuation of the input signal in steps of 10dB from −20dB to +20dB. Fine adjustment on each 10dB step is provided by potentiometer RV9 (INPUT LEVEL—FINE) in the amplifier output circuit, this control being calibrated 0 to 10dB

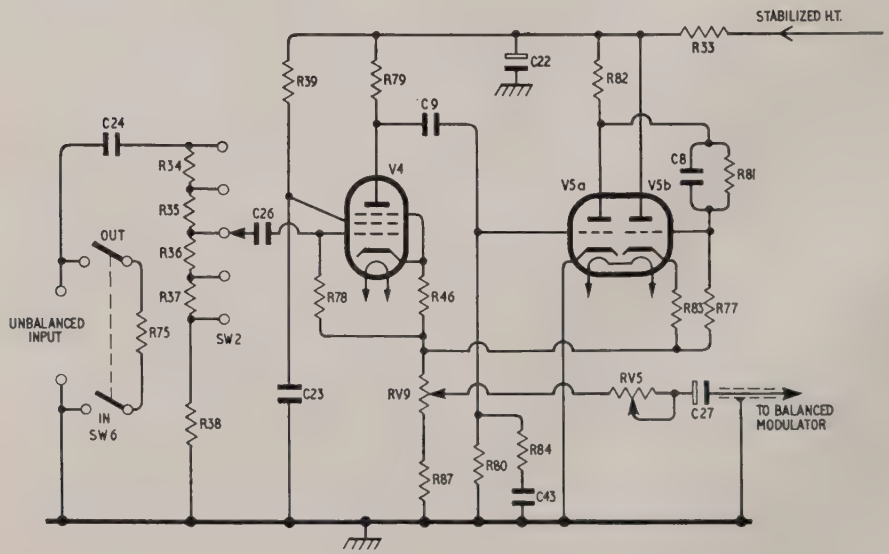

Fig. 5 Input Amplifier

(±0·3dB). The 0dB setting of the INPUT LEVEL—COARSE control is equivalent to 1mW in 600Ω, hence the equivalent input voltage range is 77·5mV to 7·75V. This can be extended to 24·5V by adjustment of RV9; for higher inputs an external attenuator is required, to prevent distortion in the input valve V4.

Pentode V4 and double triode V5a are connected in an amplifier circuit, with the entire output, developed across the load (RV9 and R87) of cathode follower V5b, applied as negative feedback to the input valve V4. This has the effect of reducing the overall gain of the amplifier to a value below unity, but enables the large range of signal inputs to be handled without producing distortion. R84 and C43, in the grid circuit of V5a, provide a degree of top-cut, the overall frequency response being within ±1dB over the working range.

The output of the amplifier is developed across the cathode load (RV9 and R87) of V5b. RV9 forms the INPUT LEVEL—FINE control, R87 being selected to give a voltage swing equivalent to 10dB between the maximum and minimum positions of RV9. The amplifier output is fed from RV9 wiper to the balanced modulator circuit via potentiometer RV5, which is used to pre-set the gain of the amplifier.

BALANCED MODULATOR

The balanced modulator circuit (fig. 6) consists of two rectifier arms and two resistance arms. The carrier output from the local oscillator is applied to the bridge circuit at junctions R13/VB2 and R14/VB1, whilst the amplifier output (signal input) is applied to the bridge between the junction VB1/VB2 and the wiper of RV1.

During operation the local oscillator is tuned to provide an upper side-frequency of 100kc/s between the carrier and the required frequency of the signal input. The carrier is suppressed by the operation of the bridge circuit, whilst the lower side-frequency is rejected by the following filter circuits.

During one half cycle of the carrier both VB1 and VB2 conduct, and the junction of VB1/VB2 is at the same potential as RV1 wiper—i.e. earth. For the next half cycle of the carrier, neither rectifier conducts, and the junction VB1/VB2 is again at earth potential. Thus the carrier is suppressed from the output, VR1 (BALANCE R) and VC6 (BALANCE C) being used to balance the resistive and reactive components of the bridge for maximum carrier-suppression. RV2 is pre-set and C10 is selected so that the BALANCE controls are approximately in their mid-positions for maximum suppression.

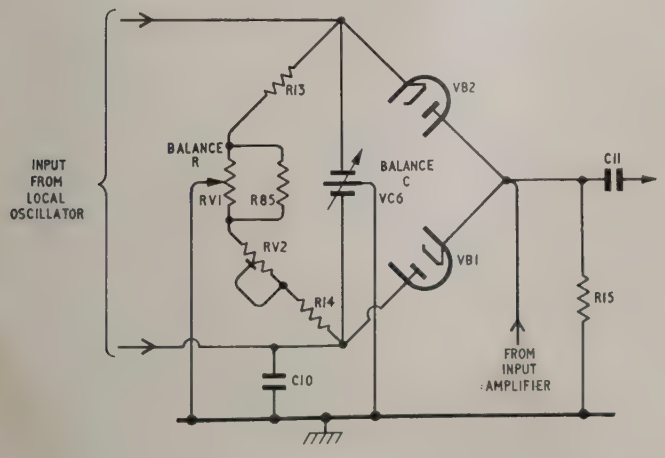

Fig. 6 Balanced Modulator

100kc/s CRYSTAL FILTER

The modulator output, which comprises the two side-frequencies produced by modulating the local oscillator carrier frequency with the selected input frequency, is developed across R15 and applied, via C11, to the control grid of amplifier valve V2a (fig. 7). The output of V2a is coupled via C13 to the control grid of cathode follower V2b, negative feedback being applied via C14 to stabilize the gain.

The cathode output of V2b is fed to the following stage via a crystal filter, which selects the upper side-frequency. Crystals X1 and X2 are sharply tuned, by C15 and C16, to a frequency of 100kc/s, the peak of the selectivity curve having a bandwidth of 10c/s. The overall Q of the filter is determined by the values of resistors R23 and R24, which are selected on test.

The second stage of the filter circuit is similar to that just described, V3 being the amplifier/cathode follower valve, and X3, X4, C20, C21, R31 and R32 being the components determining the filter characteristics. The overall gain of the filter circuit is pre-set by RV3, in the cathode circuit of amplifier valve V3a.

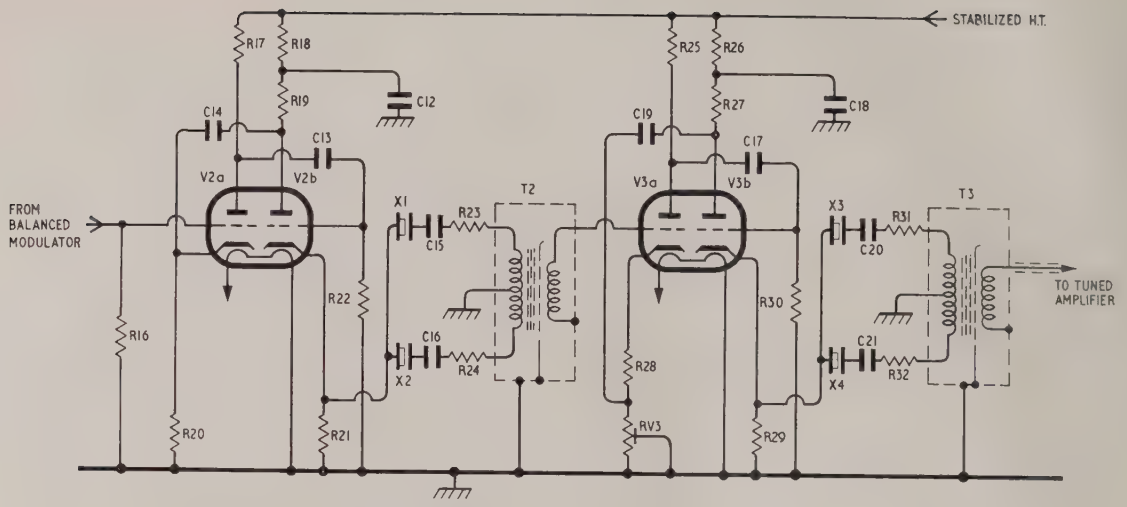

Fig. 7 100kc/s Crystal Filter

Note: The components of the crystal filter circuits are selected during test, and should not be altered. Re-alignment can be undertaken only with special test equipment. If it is necessary to remove a crystal during maintenance, it must be re-fitted to its original holder. Changing valves V2 and V3 will not affect the shape of the response curve.

100kc/s TUNED AMPLIFIER

The output from the crystal filter is fed to the control grid of the amplifier input valve V6 (fig. 8), via a potential divider network. The network consists of a series chain of high stability resistors R47 to R58, selected by rotary switch SW3 (HARMONIC LEVEL). The values of the resistors are

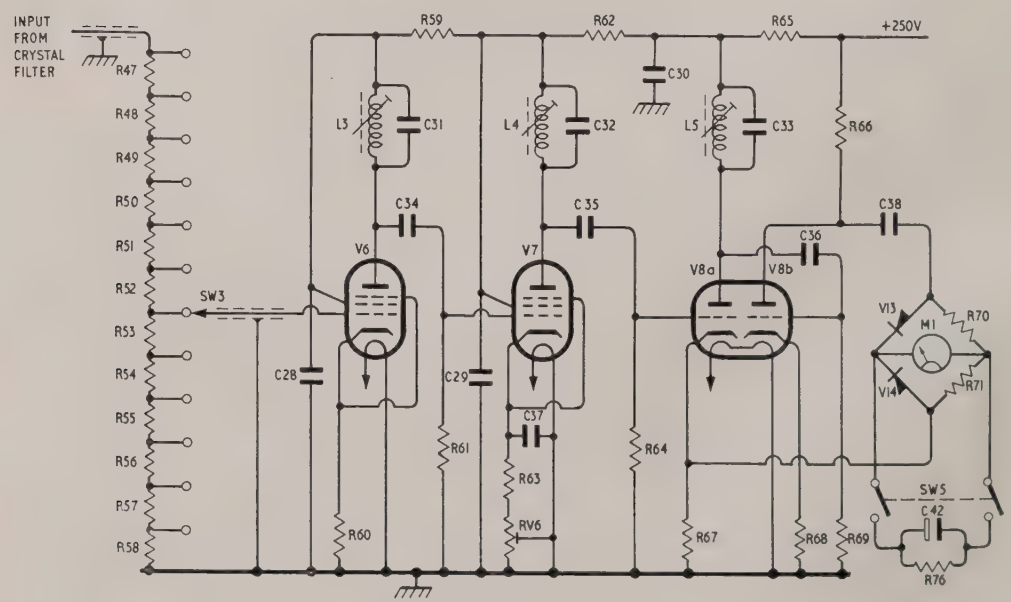

Fig. 8 100kc/s Tuned Amplifier

such that, by rotation of the switch, a successive attenuation of 5dB per step is obtained, the range covered being from 0dB to −55dB.

Each of the first three stages of the amplifier (V6, V7 and V8b) has an anode load formed by a parallel-connected capacitor and inductor, tuned to 100kc/s by the inductor. The overall gain of the amplifier is pre-set by means of RV6, in the cathode circuit of V7. The amplifier has a 3dB bandwidth of approximately 3kc/s on the centre frequency of 100kc/s.

The meter bridge circuit, V13, V14, R70 and R71, is connected in a feedback loop between the anode of the output valve V8b and the cathode of V8a. The output circuit is arranged to limit the maximum current through the meter to approximately 0·8mA, to protect the meter from overloads by excessive signal amplitudes. The meter is calibrated from +2dB to −20dB, which, in conjunction with the HARMONIC LEVEL control, gives a measuring range of +2dB to −75dB.

Parallel combination R76 and C42 can be connected across the meter by SW5 (METER TIME CONSTANT) to reduce the effects of jitter on the meter needle. The SHORT position of SW5 (i.e. R76 and C42 switched out of circuit) should be used when searching for harmonics.

MAINTENANCE

PERFORMANCE TEST

To test the performance of the analyser, a sawtooth waveform conforming as closely as possible to the ideal shape is required. This type of waveform contains both odd and even harmonics, and can usually be obtained from an oscilloscope. It will be necessary to remove any 'pips' which may be present in the sharp flyback of a waveform derived from an oscilloscope; this can be achieved by a biased diode circuit as shown in fig. 9.

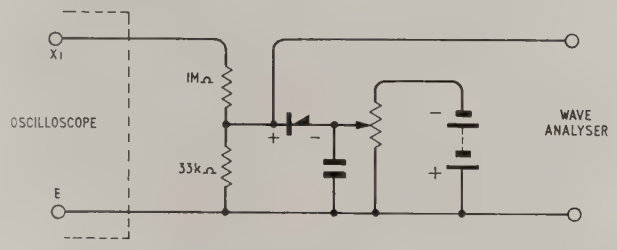

Fig. 9 Biased Diode Circuit

Typical analyser readings, together with the theoretical values, are given in Table 2.

TABLE 2

Typical Performance Figures (Sawtooth waveform)

Harmonic	Theoretical Level Below Fundamental −dB	Typical Analyser Reading −dB	Error dB
Fundamental	0	0	0
2nd	6·0	6·0	0
3rd	9·5	9·5	0
4th	12·04	12·15	0·11
5th	13·98	14·0	0·02
6th	15·56	15·5	0·06
7th	16·9	17·0	0·1
8th	18·06	18·1	0·04
9th	19·1	19·2	0·1
10th	20·0	20·1	0·1

VOLTAGES

The voltages quoted in table 3 are intended as a guide only; deviations up to ±20% may be due to variations of component values within their tolerances. The readings were obtained using an AVOmeter Model 8, with the analyser operating under the following conditions:

a No signal input.

b 600 OHMS LOAD switch (SW6) set to the OUT position.

c FREQUENCY RANGE switch (SW4) set to the HIGH position, and the tuning dial set to approximately 10kc/s.

d All other controls set to their zero positions.

TABLE 3

Typical Voltages
Unless stated otherwise, readings are with respect to earth

AVOmeter Model 8 Range	Test Points			Reading
10V a.c.	T1	across 6·3V 1·0A	secondary (Z-Z)	*6·3V a.c.
10V a.c.	T1	across 6·3V 2·5A	secondary (X-X)	*6·3V a.c.
1000V a.c.	V9	Anode	pin 1	260V a.c.
1000V a.c.		Anode	pin 7	260V a.c.
10V a.c.		Heater	across pins 4 and 5	6·3V a.c.
1000V d.c.		Cathode	pin 3	290V d.c.
1000V d.c.	C39b	Positive		250V d.c.
250V d.c.	V10	Anode/Screen	pin 5/7	200V d.c.
10V d.c.		Cath./Suppr.	pin 2/6	4V d.c.
250V d.c.	V1a	Anode	pin 1	158V d.c.
10V d.c.		Cathode	pin 3	0·8V d.c.
250V d.c.	V1b	Anode	pin 6	215V d.c.
10V d.c.		Cathode	pin 8	4V d.c.
250V d.c.	V2a	Anode	pin 1	93V d.c.
10V d.c.		Cathode	pin 3	1·2V d.c.
250V d.c.	V2b	Anode	pin 6	235V d.c.
10V d.c.		Cathode	pin 8	3V d.c.
250V d.c.	V3a	Anode	pin 1	93V d.c.
10V d.c.		Cathode	pin 3	1·2V d.c.
250V d.c.	V3b	Anode	pin 6	3V d.c.
250V d.c.	V4	Anode	pin 7	150V d.c.
250V d.c.		Screen grid	pin 8	135V d.c.
250V d.c.		Cathode	pin 3	74V d.c.
100 ohm			pin 6	0 ohms
100 ohm			pin 1	0 ohms
250V d.c.		Junction R46/RV9		27V d.c.
250V d.c.	V5	Anode	pin 1	125V d.c.
250V d.c.		Anode	pin 6	190V d.c.
250V d.c.		Control grid	pin 7	75V d.c.
250V d.c.		Cathode	pin 8	75V d.c.
250V d.c.	V6	Anode	pin 5	207V d.c.
250V d.c.		Screen	pin 7	207V d.c.
10V d.c.		Cath./Suppr.	pin 2/6	1·6V d.c.
250V d.c.	V7	Anode	pin 5	217V d.c.
250V d.c.		Screen	pin 7	217V d.c.
10V d.c.		Cath./Suppr.	pin 2/6	2V d.c.
250V d.c.	V8a	Anode	pin 1	239V d.c.
10V d.c.		Cathode	pin 3	4·1V d.c.
250V d.c.	V8b	Anode	pin 6	175V d.c.
10V d.c.		Cathode	pin 8	2·5V d.c.

* Loaded.

RE-ADJUSTMENT AND RE-ALIGNMENT

Re-adjustment and re-alignment should not be contemplated unless it is proved to be absolutely necessary, and the procedure should be adopted only by skilled technicians. The equipment required is:

a Variable oscillator having a range from 20c/s to 150kc/s.

b Multi-range test meter (e.g. AVOmeter Model 8).

c Oscilloscope (e.g. Cossor Type 1035).

d Component bridge (e.g. Wayne Kerr Type B521).

e Valve voltmeter (e.g. Wayne Kerr Type M121).

It will be necessary to remove the equipment from its case, by releasing the four screws securing the front panel and the two screws securing the rear of the chassis.

100kc/s tuned amplifier

Set the HARMONIC LEVEL control to the −55dB position, and apply a 100kc/s signal of 60μV amplitude to the control grid of V6 (pin 1). Adjust RV6 (cathode circuit of V7) to produce an indication of 0dB on the panel meter.

L3, L4 and L5 should be tuned to give maximum response at 100kc/s.

100kc/s crystal filter

The response of the crystal filter circuit (X1, X2, X3, X4) can be adjusted only with the aid of special test equipment, and this circuit should not be altered in any way. The response of the filter is not affected by changing valves V2 and V3.

To adjust the overall gain of the crystal filter stage, connect a 100kc/s signal of 10μV amplitude to the control grid of V2a (pin 2) and adjust RV3 (cathode circuit of V3a) to produce a deflection of 0dB on the panel meter.

Local oscillator

The frequency calibration of the oscillator is not normally upset by changing the oscillator valve V1. Should the calibration be affected, the oscillator can be re-calibrated as detailed in the following procedure, after allowing one hour for the analyser to warm up.

1kc/s to 20kc/s scale:

a Set the FREQUENCY RANGE control to the HIGH position, and the FINE FREQUENCY control to the centre dot on its scale. These controls must not be moved again during this part of the re-calibration procedure.

b Apply a signal of 1kc/s ±1c/s to the input terminals, and set the main tuning dial to 1kc/s. Adjust the trimmer VC4 for maximum deflection on the panel meter.

c By varying the frequency of the applied signal, check that the other calibration points agree with the input frequency to within ±2%.

Zero to 1200c/s scale:

d Set the FREQUENCY RANGE control to the LOW position, and set the main tuning dial to zero. Do not move the FINE FREQUENCY control.

e With no signal input adjust VC2 for maximum deflection on the meter. Apply signals of different frequencies in turn to the input terminals, and check that the calibration points agree with the input frequency, to within ±2%. Should the dial calibrations not agree, the values of the oscillator components may have altered, or the cursor may have moved on its shaft. Check that the value of L2 is 2.85mH ±1%, and check the variable capacitor VC1 for mechanical movement. Then:

f Apply a signal of 1kc/s to the input terminals and set the main tuning dial to 1000c/s (low scale). Adjust VC3 for maximum deflection on the panel meter.

g Re-set the main tuning dial to zero, and adjust VC2 for maximum deflection on the panel meter if necessary.

h Repeat the adjustments of VC3 and VC2 until the calibration is satisfactory (i.e. within ±2% of input frequency).

Balanced modulator

If it is impossible to obtain suppression of the carrier frequency by adjustment of the BALANCE R and BALANCE C controls:

a Set the BALANCE R and BALANCE C controls to the mid-positions of their travel.

b Adjust RV2 and C10 until the carrier balance is obtained.

C10 is a fixed capacitor with a nominal value of 100pF, selected during test. It may be necessary to reconnect C10 from the other side of VC6 to earth.

Jitter

A certain amount of jitter is unavoidable with normal a.c. supplies. If the power surges are excessive, adjustment of RV7 (see under heading 'Bridge shunt stabilizer', this section) may help.

It may also be advisable to operate the Waveform Analyser from an a.c. stabilizer capable of suppressing power fluctuations.

Excessive jitter may also be caused by V1 being defective, or RV1, RV2 or VC6 becoming noisy or developing a bad contact. The faulty component should be replaced. The pick-up of local radio-signals (especially morse) which beat with the local oscillator output will also cause jitter.

Jitter is most pronounced when the local oscillator is operating at frequencies near 100kcs/.

Input amplifier

The fixed resistor R87 has been selected to give a voltage swing of 10dB between the minimum and maximum positions of RV9. Valves V4 and V5 do not have to be specially selected. The hum level of the amplifier can be checked using the Waveform Analyser (see the Operating Instructions); if this is excessive RV8 (across the 6·3V 1·0A winding of the mains input transformer) should be suitably adjusted.

To adjust the gain of the amplifier:

a Set the INPUT LEVEL controls and the HARMONIC LEVEL control to their zero positions.

b Suppress the carrier, and apply a 1kc/s signal corresponding to 0·775V into 600Ω (1mW) to the input terminals, setting the frequency controls accordingly.

c Adjust RV5 for a reading of 0dB on the panel meter.

Bridge shunt stabilizer

Connect a cathode-ray oscilloscope across C41, and set the oscilloscope controls for maximum sensitivity. Adjust RV7, in the cathode circuit of V10, for minimum hum and 'jitter' on the stabilized h.t. line.

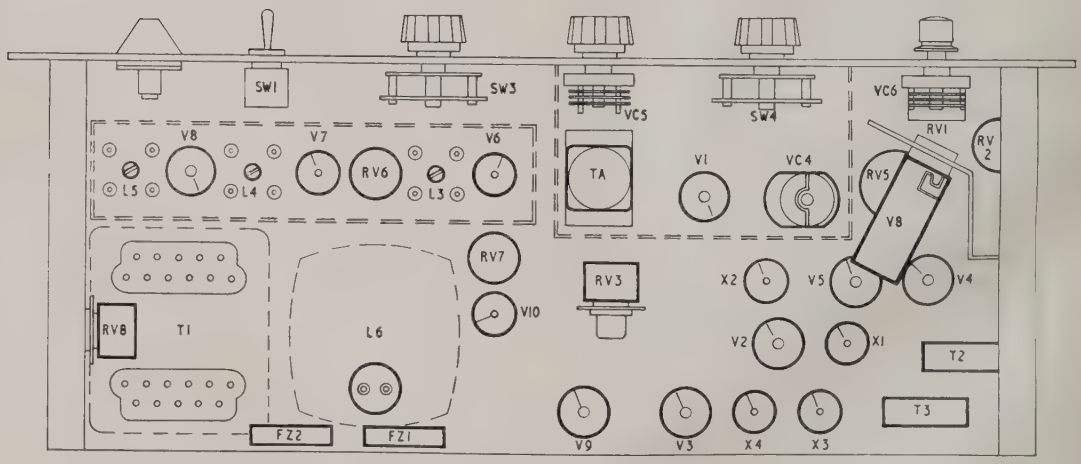

Fig. 10 Location of Major Components

COMPONENT LIST

** Starred components are selected on test and their values vary with each equipment; figures quoted are intended as a guide only*

Circuit Reference	Description		
R1	5Ω	±20%	
R2	22kΩ	±10%	
R3	100kΩ	±10%	
R4	Not fitted		
R5	100kΩ	±10%	
R6	330Ω	±10%	
R7	Not fitted		
R8	220kΩ	±10%	
R9–R12	Not fitted		
R13	220Ω	± 5%	
R14	150Ω	±10%	
R15	22kΩ	± 5%	
R16	100kΩ	±10%	
R17	100kΩ	±10%	
R18	4·7kΩ	±10%	
R19	1·2kΩ	±10%	
R20	820Ω	±10%	
R21	1·2kΩ	±10%	
R22	470kΩ	±10%	
R23	*2kΩ	±10%	
R24	*4kΩ	±10%	
R25	100kΩ	±10%	
R26	4·7kΩ	±10%	
R27	1·2kΩ	±10%	
R28	470Ω	±10%	
R29	1·2kΩ	±10%	
R30	470kΩ	±10%	
R31	3kΩ	±10%	
R32	4kΩ	±10%	
R33	1kΩ	±10%	
R34	68·38kΩ	± 1%	
R35	21·62kΩ	± 1%	
R36	6·838kΩ	± 1%	
R37	2·162kΩ	± 1%	
R38	1kΩ	± 1%	
R39	220kΩ	±10%	
R40–R45	Not fitted		
R46	2·2kΩ	± 5%	
R47	15·3kΩ	± 1%	
R48	8·62kΩ	± 1%	
R49	4·87kΩ	± 1%	
R50	2·71kΩ	± 1%	
R51	1·53kΩ	± 1%	
R52	862Ω	± 1%	
R53	487Ω	± 1%	
R54	271Ω	± 1%	
R55	153Ω	± 1%	
R56	86·2Ω	± 1%	
R57	48·7Ω	± 1%	
R58	62·1Ω	± 1%	
R59	3·3kΩ	±10%	
R60	200Ω	± 5%	

Circuit Reference	Description		
R61	*100kΩ	±10%	
R62	1kΩ	±10%	
R63	100Ω	±10%	
R64	*150kΩ	±10%	
R65	1kΩ	±10%	
R66	33kΩ	± 5%	
R67	2·7kΩ	±10%	
R68	1kΩ	±10%	
R69	220kΩ	±10%	
R70	22kΩ	± 5%	
R71	22kΩ	± 5%	
R72	470Ω	± 5%	
R73	2·2mΩ	±10%	
R74	150Ω	±10%	
R75	600Ω	± 1%	
R76	2·2kΩ	±10%	
R77	470kΩ	±10%	
R78	100kΩ	±10%	
R79	47kΩ	±10%	
R80	1mΩ	±10%	
R81	1mΩ	±10%	
R82	22kΩ	±10%	
R83	220Ω	±10%	
R84	*1·8kΩ	±10%	
R85	10Ω	±10%	
R86	Not fitted		
R87	*2·7kΩ	±10%	
R88	390Ω	±10%	
C1	*110pF	± 5%	350V
C2	*1000pF	± 2%	500V
C3	0·1μF		350V
C4	100pF	±20%	350V
C5	0·01μF	±10%	350V
C6	0·01μF	±10%	350V
C7	0·01μF		350V
C8	0·01μF		350V
C9	0·01μF		350V
C10	*100pF		350V
C11	100pF	±20%	350V
C12	0·1μF		350V
C13	100pF		350V
C14	0·01μF		350V
C15	*	Normally not fitted	
C16	*	Normally not fitted	
C17	100pF		350V
C18	0·1μF		350V
C19	0·01μF		350V
C20	*	Normally not fitted	
C21	*	Normally not fitted	
C22	16μF		350V
C23	Not fitted		

Circuit Reference	Description		
C24	0·5μF		500V
C25	Not fitted		
C26	0·1μF		350V
C27	2μF		150V
C28	0·01μF		350V
C29	0·01μF		350V
C30	0·01μF		350V
C31	1000pF	± 5%	
C32	1000pF	± 5%	
C33	1000pF	± 5%	
C34	1000pF	±20%	350V
C35	1000pF	±20%	350V
C36	1000pF	±20%	350V
C37	0·01μF		350V
C38	0·01μF		350V
C39a	16μF		350V
C39b	32μF		
C40	0·5μF		350V
C41	16μF		350V
C42	2000μF		6V
C43	47pF	± 6%	
RV1	10Ω		
RV2	100Ω		
RV3	1kΩ		
RV4	Not fitted		
RV5	10kΩ		
RV6	500Ω		
RV7	500Ω		
RV8	100Ω		
RV9	5kΩ		
VC1	3-gang: 12–117pF 14–532pF 14–532pF		
VC2	3 to 30pF		
VC3	3 to 30pF		
VC4	3·8 to 50pF		
VC5	3 to 10pF		
VC6	50–0–50pF		

Circuit Reference	Description
L1	1·5H
L2	2·85mH
L3, L4, L5	Core in: 1·65mH Core out: 3·3mH ±20%
L6	50H 80mA
V1	12AU7
V2	12AT7
V3	12AT7
V4	6BR7
V5	12AT7
V6	EF91
V7	EF91
V8	12AT7
V9	6V4/EZ80
V10	EF91
V11, V12	Not fitted
V13	WG7B
V14	WG7B
VB1/2	EB91
X1	JCF/193 crystal 100kc/s ±6c/s
X2	JCF/193 crystal 100kc/s −6c/s
X3	JCF/193 crystal 100kc/s +6c/s
X4	JCF/193 crystal 100kc/s −6c/s
M1	Meter 0 to 0·5mA ±1%, 100Ω ±5% Ernest Turner Type 505
FZ1	2A (4A for 110V to 120V mains) Belling Lee L356
FZ2	2A (4A for 110V to 120V mains) Belling Lee L356
SW1	on/off 2-pole toggle 8370/B3
SW2	1-pole 5-way BNSF Type H
SW3	1-pole 12-way BNSF Type H
SW4	2-pole 2-way 60° BNSF Type H
SW5	on/off 2-pole toggle 8370/K8
SW6	on/off 2-pole toggle 8370/K8

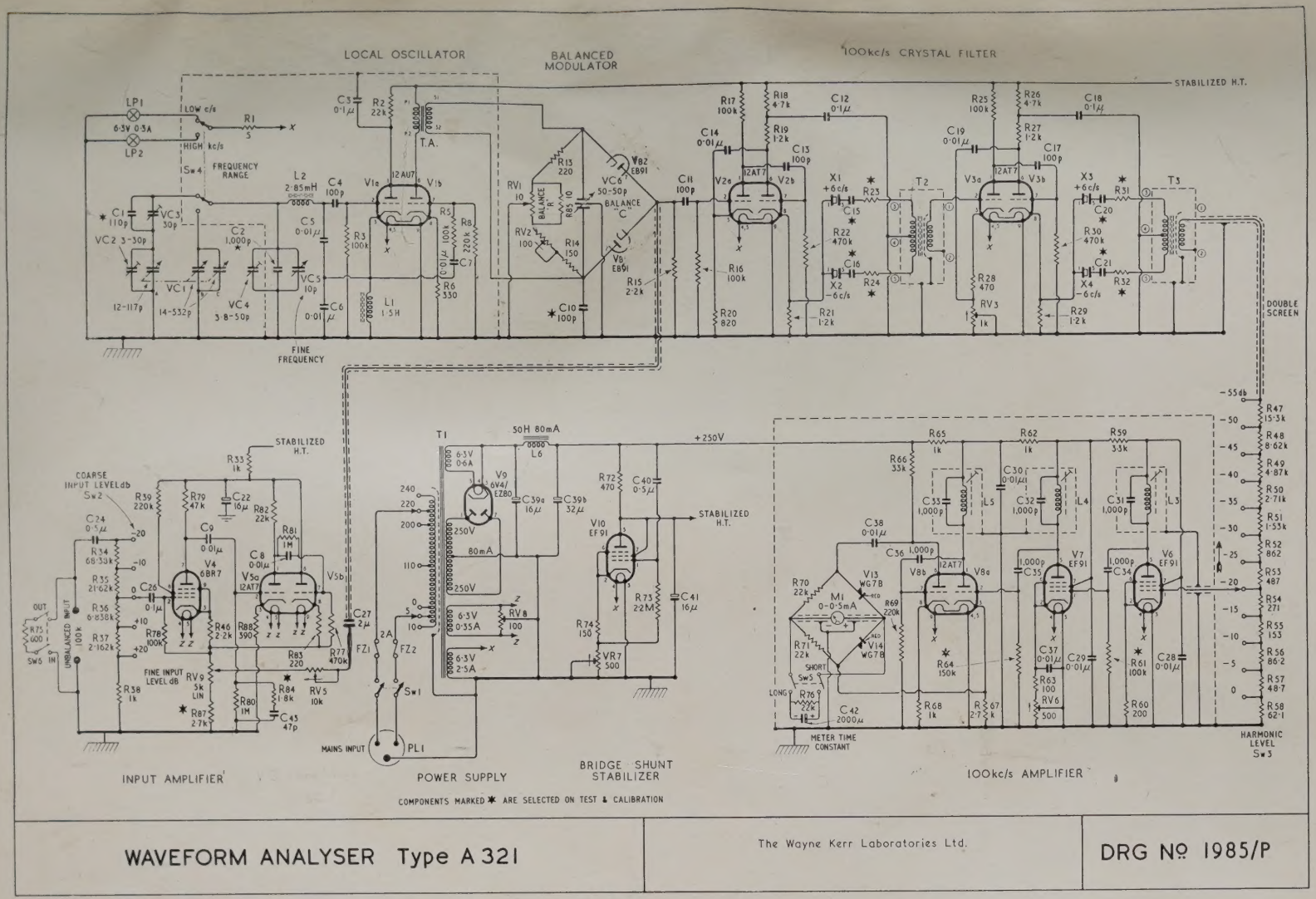

Fig. 11 Circuit Diagram

MP MASTER
MA24490

WAYNE KERR

TELEPHONE: MALden 2202
TELEGRAPH: WAYNKERR, NEW MALDEN

SALES AND SERVICE
44 COOMBE ROAD, NEW MALDEN, SURREY

TELEPHONE: LOcust 8-6820
TELEGRAPH: WAYNKERR, PHILADELPHIA

WAYNE KERR CORPORATION
1633 RACE STREET, PHILADELPHIA 3, PENNSYLVANIA

Publication TP8

Printed in England IT/7/60/5C